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The Relation between Loom Weight and Finished Weight of Cloth

and a Practical Rule for Finishing to Correct Weight and Regain.

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The Relation between

Loom Weight and Finished Weight

of Cloth

Introduction.

In the following paper a method is given for finishing pieces of approximately the correct condition (16% regain).

Usually pieces are finished (tentered, etc.) too dry, and moisture is added towards the end of finishing by spraying or the like.

This final damping should be adjusted in accordance with the following brief rules, which are explained in detail in the paper.

1. Keep a record of the bulb differences in the weaving shed.
2. Add together twice the bulb difference for the last day in the loom and once the bulb difference for the three preceding days. Divide the sum by 5, giving the average bulb difference for calculation.
3. Take the regain allowance (+ or —) from Table V.
4. If known, take the actual scouring loss. For Worsteds an average figure is 3.3% (—). (Woollens vary so much in oil content and dirt that it is more difficult to give an average figure).
5. From Tables VI. and VII. take the dyeing gain (+) or loss (—).
6. The % correction is obtained by adding (+) or subtracting (—) the amounts found in paragraphs 3, 4 and 5. Multiply this by the loom weight and divide by 100 for the total correction.
7. The *correct finished weight* is the loom weight plus or minus the total correction.

In ordinary practice firms will probably find it convenient to make up once for all a set of tables for some half dozen types of cloth, showing only the average bulb difference and the correction on loom weight per 100 lbs.

Standard Regain in Cloth.

The standard of condition for cloth is 16%, i.e., the " true weight " of a piece is equal to its dry weight with 16% of this dry weight added. If a piece is sold on the basis of its actual weight at the time there are three possibilities :

1. That the piece is at the standard regain of 16% ; in which case the transaction is a perfectly fair one for both buyer and seller.
2. That the piece is at a higher regain than 16% ; in which case the seller is selling and the buyer is buying water at the price of wool.
3. That the piece is at a lower regain than 16% ; in which case the seller is giving away and the buyer receiving wool for nothing.

It is thus a matter of great commercial importance that the changes of weight which occur from the yarn to the finished cloth should be accurately investigated, in order that a method may be devised for controlling within the limits of commercial accuracy the finished weight of cloth.

In the adjustment of the finished weight to the loom weight there are four sources of uncertainty :—

1. as to the "true" loom weight.
2. as to the change of weight during scouring.
3. as to the change during dyeing (in the case of piece-dyed goods).
4. as to the change during finishing.

With regard to (1) it may be pointed out that if the "true" counts of both warp and weft were known, then the "true" loom weight would be a mere matter of the number of ends and picks and the "take up," and would be quite independent of the atmospheric conditions prevailing at the time of weaving, so that the only adjustments necessary would be for scouring, dyeing and finishing changes.

In general, however, even in cases where the weft yarn is tested for condition, the condition of the warp is unknown, so that the only guide to the final "true" weight of the cloth is its weight off the loom, and the only method of finishing to a correct weight is to finish to a certain percentage of the loom weight. Now the variation of atmospheric conditions during the weaving of different pieces will lead to variation in the final results. A piece woven in a very dry atmosphere will be under-conditioned relative to a piece woven in a damp atmosphere. Hence to get uniform results allowance should be made for the atmospheric conditions during weaving. The percentage of the loom weight to which the cloth is finished should be greater or less according as the atmospheric conditions during weaving are drier or damper. The making of such an allowance involves in the first place the question of the relation between regain and atmospheric humidity and temperature (the hygrometric state of the atmosphere).

The Relation between Regain and the Hygrometric State of the Atmosphere.

The hitherto published data are very scanty. The only extended researches are those of Schloesing and of Hartshorne. Of these the work of the former is much the more reliable, that of the latter being very faulty ; and in view of the much earlier work of Schloesing quite devoid of any real scientific value.

The work of Schloesing, though quite reliable as far as it goes, is limited with regard to the range of material investigated, so that we cannot apply his results to the special case of cloth, as it leaves the loom. We may, however, deduce an important principle from his work. This principle, which has previously been enunciated in Pamphlet No. 1, may be stated as follows:

The regain of wool in equilibrium with a given atmosphere depends only on the difference between the temperatures of the bulbs of the wet-and-dry-bulb hygrometer placed in that atmosphere. It does not depend on the actual temperatures of the bulbs.

This statement, which is not rigorously accurate, but sufficiently accurate for the present purpose, follows from the following considerations. A given relative humidity corresponds to a lower regain the higher the temperature. Thus according to Schloesing, 50% humidity corresponds to 13.5% regain at 12°C., and to 12.1% at 35°C. In mathematical language, the regain is a function of two variables, relative humidity and temperature. In order to get the same regain at a higher temperature the relative humidity would have to be increased. Thus according to Schloesing 59% humidity at 35°C. gives the same regain as 50% at 12°C.

Let us now consider the bulb difference. Instead of considering the same relative humidity at different temperatures, let us consider the same bulb difference at different temperatures. According to Glaisher's Tables a given bulb difference corresponds to a higher humidity the higher the temperature. Thus 5°F. corresponds to 69% humidity at 54°F. (12°C.) and to 78% at 95°F. (35°C.) According to Schloesing these correspond to regains of 15.9% and 16.1% respectively; that is to say that from a practical point of view the regain depends only on the bulb difference.

In the following table are compiled, first the humidities corresponding to given bulb differences at 12°C. and 35°C. (from Glaisher's Tables), and secondly corresponding regains (from Schloesing's curves).

TABLE I.

Bulb Difference.	Humidity corresponding to		Corresponding Regain at		Increment of Regain.
	12°C. (54°F.)	35°C. (95°F.)	12°C. (54°F.)	35°C. (95°F.)	
	%	%	%	%	
1	93	95	26.8	26.9	0.1
2	86	91	22.5	23.1	0.6
3	80	86	20.0	19.9	—0.1
4	74	82	18.0	18.2	0.2
5	69	78	16.9	17.1	0.2
6	64	74	15.9	16.1	0.2
7	59	70	15.0	15.4	0.4
8	55	66	14.3	14.6	0.3
9	51	63	13.6	14.1	0.5
10	47	60	13.0	13.7	0.7

The range of temperature (39°F.) is very large and the change of regain quite small, so that it may safely be said that in practice we may regard the regain as dependent on the bulb difference only. This consideration introduces a considerable practical simplification. There is no need for tables to convert the readings of the hygrometer into relative humidities. The bulb difference, irrespective of the actual temperatures, is all that matters.

It would not be safe to apply the figures given in the above table to the case of cloth as it leaves the loom. We do not know the exact treatment of the samples of wool used by Schloesing, but it may safely be said that they were freer from grease and dirt then a piece from the loom. The regains given in the table will, therefore, be unduly high. It is necessary, therefore, to experiment with actual samples of cloth in the grey.

The Regain of Cloth in the Grey.

The data given in this section are extracted from numerous data which we have been accumulating relative to the regain of wool in different forms. They relate to a number of samples of cloth in the grey. Each sample was subjected to different humidities in the humidity room (at a temperature of 72.5°F.). Each humidity was maintained for several days. The samples were weighed from day to day, and there was no doubt that they had come into equilibrium with the air of the room. The humidity of the air (which is always a difficult quantity to estimate accurately) was measured by five different methods, which gave concordant results.

In the following table are given the mean values of the regain for the different samples together with the values of the relative humidity, the bulb difference (ordinary wet-and-dry-bulb hygrometer), and Schloesing's values of the regain. As is to be expected, our values, which relate to a greasy dirty piece, are rather lower than those of Schloesing.

TABLE II.

Bulb Difference (°F.)	Our values of Regain (%).	Schloesing's Values Regain (%).	% Humidity.
2	20.5	22.8	89
3	18.0	20.0	84
4	16.2	18.1	79
5	15.2	17.0	74
6	14.4	16.0	69
7	13.7	15.2	65
8	13.1	14.4	61
9	12.6	13.8	57
10	12.1	13.3	54

We will now consider how these results may be applied to the practical problem of making allowance for the variations of atmospheric humidity during weaving.

The Adjustment of the Loom Weight to Standard Condition.

The atmospheric conditions will in general be varying during weaving, and it is necessary to arrive at some kind of average. If the piece were in open form during the whole of the weaving process the regain would correspond most nearly to the bulb difference on the last day of weaving. If, on the other hand, the piece did not gain or lose at all in the rolled up form, the regain would correspond to the mean bulb difference for all the days. The truth lies somewhere between these two extremes, and the method adopted by Messrs. Hewitt, Haigh & Wilson Ltd. may be regarded as sufficiently near the truth for practical purposes. This is to count the last day's reading twice in taking the mean, or in mathematical language to adopt a "weighted" mean, attaching a double "weight" to the last day's readings.

The percentage change necessary to reduce the actual loom weight to the 16% standard is easily calculated. Thus if the mean bulb difference is 7°F., a piece weighing 113.7 units (see Table II.) should weigh 116, or a piece weighing 100 should weigh 102.0. The loom weight requires therefore 2.0% adding to it to bring it up to the standard. The necessary allowances to bring the loom weight up to standard are as follows:

TABLE III.

Bulb Difference.	% Allowance.
2	3.7 to be deducted
3	1.7 ,,
4	0.2 ,,
5	0.7 to be added
9	1.4 ,,
7	2.0 ,,
8	2.6 ,,
9	3.0 ,,
10	3.5 ,,
11	3.8 ,,

The above allowance eliminates the effect of varying atmospheric humidity during the weaving of different pieces, so that it only remains to consider the change of weight during finishing. This point is investigated in the next section.

An Investigation of the Changes of Weight during Scouring, Dyeing and Finishing.

A length of grey worsted twill cloth (16 oz. 70's quality coating serge), was divided into four parts P1, P2, P3, P4, as nearly equal as possible. The samples were then placed in the humidity room to even up. After a few days their weights attained the following constant values:

P1	P2	P3	P4
1037.8	1048.1	1060.7	1058.2 (grms.)

A portion of P1 was then dried out, and from this dry weight the dry weights of the four samples calculated. These were as follows:

P1	P2	P3	P4
915.2	924.3	935.4	933.0

The three samples P2, P3 and P4 were then sent away. P2 was returned scoured. P3 was returned scoured and dyed (alizarine blue). P4 was returned scoured, dyed and finished. The samples were then placed in the humidity room to even up, and the dry weight of each determined by drying out a portion of each. These dry weights, together with that of P1, are given below:

P1	P2	P3	P4
915.2	880.6	910.5	906.1

Calling the dry weight in the grease of each sample 100, these figures become

P1	P2	P3	P4
100.0	95.2	97.4	97.1

We see that there is a total loss of 2.9% made up of

a loss of 4.8% in scouring,
a gain of 2.2% in dyeing,
a loss of 0.3% in finishing.

Reckoned on the conditioned weight (16% regain) these are

a loss of 4.1% in scouring,
a gain of 1.9% in dyeing,
a loss of 0.3% in finishing.

Allowances.

We thus see that for this cloth an allowance of 2.9% on the dry weight or 2.5% on the conditioned weight is necessary. A piece coming from the loom in standard condition must be finished 2.5% lighter in order to be in standard condition at the end. A piece coming from the loom not in standard condition would require in addition the allowance for atmospheric conditions during weaving (see previous section). Thus for a mean bulb difference of 7°F. a piece weighing 100 units off the loom would weigh 102 0 in standard condition and would finish at 99.4, so that the total allowance would be 0.6 units. The total allowance for this particular piece is shown in the following table :

TABLE IV.

Bulb Difference °F.	Correct Conditioned Wt. of piece 100lb. off the Loom.	2.5% of this Conditioned Wt. (dyeing & finishing).	Correct Finished Weight.	Total % Allowance on Loom Weight.
2	96.3	2.4	93.9	6.1 to be deducted
3	98.3	2.5	95.8	4.2 ,,
4	99.8	2.5	97.3	2.7 ,,
5	100.7	2.5	98.2	1.8 ,,
6	101.4	2.5	98.9	1.1 ,,
7	102.0	2.6	99.4	0.6 ,,
8	102.6	2.6	100.0	0.0
9	103.0	2.6	100.4	0.4 to be added
10	103.5	2.6	100.9	0.9 ,,
11	103.8	2.6	101.2	1.2 ,,

The total allowance may be obtained sufficiently accurately for all practical purposes by simple addition (in the algebraic sense) of the two percentage allowances. Thus for 5° bulb difference the total allowance is 0.7% (to be added) for loom condition, and 2.5% (to be deducted) for finishing losses, giving a total of 1.8% (to be deducted).

The above figure for the scouring loss (4.1% on the weight in standard condition) seems unusually high. According to some figures which have been submitted to us 3.3% is nearer the average, or 3½% for the total loss of a piece which has not been dyed in the piece. In this case the total allowances would be ;

TABLE V.

Bulb Difference.	Regain Allowance %.	Total Allowance %
2	—3.7	7.2 to be deducted
3	—1.7	5.2 ,,
4	—0.2	3.7 ,,
5	+0.7	2.8 ,,
6	+1.4	2.1 ,,
7	+2.0	1.5 ,,
8	+2.6	0.9 ,,
9	+3.0	0.5 ,,
10	+3.5	0.0
11	+3.8	0.3 to be added

Gains and Losses in Dyeing.

The change of weight owing to dyeing will vary very much with different dyes. This point is at present under investigation, and numerous data have already been accumulated.

A few examples of the changes of dry weight in dyeing are given in the following tables:

TABLE VI.

WHITE WORSTED: 9 oz. Dress Cloth.
2/60's warp of 64/70's quality
single weft, 56's quality.

Dye.	Change of Weight %
Logwood Black on Chrome	2.24 gain
,, ,, ,, +burl-dyed tannin and iron	2.51 ,,
Blue: Indigo pure medium shade	3.85 ,,
Blue: with red bottom on chrome full shade	5.08 ,,
Blue: Indigo, topped with chrome colour full shade	4.17 ,,
Grey: acid colour pale with acetic acid	0.16 loss
Light grey: acid colour pale with sulphuric acid	1.16 gain
Light blue: acid colour full shade with acetic acid	0.61 ,,
Brown: acid colour full shade with sulphuric acid	2.65 ,,
Acid black	4.34 ,,
Blue: after chrome blue (navy)	1.78 ,,
Black: diamond black	2.80 ,,

TABLE VII.

MEDIUM WOOLLEN: 15 oz. 48/50's quality.

			Change of Weight % Series A	Series B
1	Acid Black		7.95 gain	8.25 gain
2	Logwood Black		4.58 ,,	4.96 ,,
3	Navy		1.63 ,,	4.58 ,,
4	Stripped and dyed fawn		4.82 loss	1.27 loss
5	Fawn		0.41 gain	0.25 gain
6	Indigo		1.86 ,,	1.66 ,,
7	Diamond	Black	1.25 ,,	0.97 ,,
8	Aliz.	Navy	1.16 ,,	1.27 ,,
9	,,	Fawn	0.15 loss	0.20 loss
10	,,	Grey	0.56 ,,	0.37 ,,
11	,,	Dark Blue	1.25 gain	1.32 gain
12	,,	Nigger Brown	0	0

TABLE VIII.

COTTON WARP SHODDY: 17 oz.

	Change of Weight %
Acid Black and burl-dyed iron	4.39 gain
Logwood Black ,,	4.93 ,,
Navy ,,	2.61 ,,
Brown and cotton dyed	2.73 loss
Light Blue ,,	4.34 ,,

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APPENDIX.

(Loom Weight Correction).

We add herewith the (Table A) in use by a certain firm, and an analys is of the results for 8½ months (Table B).

It will be seen that the correction is nearly always to be added, actual loom weight being slightly less than corrected loom weight.

On 23% of the days ½ lb. or more had to be added to loom weight of each piece. On 17½% of the days, 1 lb. or more had to be added.

Bulb differences in the shed were taken at 9 a.m., 2 p.m., 4 p.m., averaged for the day, and entered up.

For getting the weight correction for the day (i.e., for pieces weighed off the loom that day) :—

Twice the bulb difference for the day is added to once the bulb difference for each of the two preceding days. The sum is divided by four, giving the average bulb difference.

From Table A the *correction for the day* is read :

TABLE A.

Bulb Difference.	Correction on Loom Weight of 65 lb. Pieces.
2	—2 lb.
2½	—2 ,,
3	—1½ ,,
3½	—1 ,,
4	— ½ ,,
4½	
5	Normal
5½	
6	+ ½ lb.
6½	+1 ,,
7	+1 ,,
7½	+1½ ,,

Allowances for scouring and dyeing losses or gains have to be made in addition.

Table B.

Record of Daily Correction on 65 lb. Piece.

1923 1924

Date of Month.	July.	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1		N	N	N	N	+1	N	N	
2		N		N	N		N	N	
3	N	N	N	N	N	+½	N		
4	N	N	N	N		+½	N	N	
5	N		+½	N	N	+1	N	N	
6	+1	+½	N	N	+½	+½		N	
7	+1	+½	N		+½	N	N	N	
8		+½	N	N	+1	+½	N	N	
9	+1	+½		N	+1		+½	+½	
10	+1	N	N	+1	+1	+½	+½		+1
11	N		+½	+1		+½	+½	N	+1½
12	+½		+1	+1	+½	N	+1	+½	+1
13	+1		N	+1	N	N		+½	+1
14	+1		N		N	N	+½	+1	+1
15			N	+1	N	+½	+½	+1	+1
16	+½			+1	N		+½	+1	
17	+1		N	+½	N	+½	+½		+1
18	+1		N	+½		N	+½	+1	+1
19	+½		N	N	N	N	N	+½	+1
20	+½	N	N	+½	+½	N		+1	
21	+½	N	N		+½	+1	N	+1	
22		N	N	N	+½		N	+1	
23	N	N		N	+½		—½	+1	
24	—1	N	N	N	+½		N	Opera-	
25	N	N	N	N			N	tor ill	
26	N		N	N	+½		N		
27	N	N	N	N	N	N			
28	+½	N	N		+½	N	N		
29		N	N	N	+½	N	N		
30	N	N		N	+½		N		
31	N	N		N		N	N		

Table C.

Analysis of 550 Bulb Difference Records.

Bulb Difference.	No. of Readings.	% of Total Number of Readings.
2°	3	.55%
3°	15	2.72%
4°	61	11.09%
5°	135	24.55%
6°	222	40.36%
7°	74	13.45%
8°	32	5.82%
9°	3	.55%
10°	5	.91%
	550	100.00

Table D.

Analysis of 113 Daily Weight Corrections.

	Number of days.	
Normal	113	56%
+½ lb.	47	24%
+1 ,,	38	19%
+1½ ,,	1	½%
—½ ,,	1	½%
—1 ,,	1	½%
	201	100 approx.

All on 65 lb. piece.

REGAIN.

EXPLANATORY NOTE.

Relative Humidity. This is a numerical measure of the dryness or dampness of the air. If the air is saturated and will absorb no more moisture, we say the relative humidity is 100%. If the air is absolutely devoid of moisture, we say the relative humidity is 0%. In this climate the natural relative humidity of the atmosphere may be very low (as on a bright frosty morning), or it may be nearly 100% (as in misty weather).

The degree of dryness or dampness of the atmosphere depends not merely on the amount of moisture in a given volume of air, but on the relation between this amount and the amount required to saturate the air. This latter amount varies very rapidly with the temperature. Thus at 40°F. it is 2.9 grains per cubic ft.; at 50°, 4.1; at 60°, 5.8; at 70°, 8.0; and at 80°, 11.0. Roughly speaking, a rise of temperature of 20°F. doubles the amount of moisture required to saturate the air.

It follows, therefore, that if we are merely told the amount of moisture in the air, say 4 grains per cubic foot, we have no information as to the dryness or dampness of the air. If the temperature were 50°F. the air would be nearly saturated; if 70°F., the air would be fairly dry, containing only half the amount of moisture required to saturate it; at a still higher temperature the air would be still drier.

The state of the atmosphere with respect to dryness and dampness is thus specified by the actual moisture content expressed as a fraction or a percentage of the amount required to saturate the air. Thus 4 grains per cubic ft. corresponds to 98% relative humidity at 50°F. and to 50% at 70°F. In the following table are given as an illustration of this the grains per cubic ft. corresponding to different percentage humidities at different temperatures.

Temp. °F.	Relative Humidity (Percentage). 100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
40	2.86	2.57	2.09	2.00	1.72	1.43	1.14	0.86	0.57	0.29
50	4.10	3.69	3.28	2.87	2.46	2.05	1.64	1.23	0.82	0.41
60	5.77	5.19	4.62	4.04	3.46	2.89	2.31	1.73	1.15	0.58
70	8.01	7.21	6.41	5.61	4.81	4.01	3.20	2.40	1.60	0.80
80	10.98	9.88	8.78	7.69	6.59	5.49	4.39	3.29	2.20	1.10
90	14.85	13.37	11.88	10.49	8.91	7.43	5.94	4.46	2.97	1.49
100	19.84	17.86	15.87	13.89	11.90	9.92	7.94	5.95	3.97	1.98

Regain. It is common knowledge that various substances such as wool, cotton, linen, paper, leather, tobacco, wood, etc., absorb moisture to a degree depending upon the atmospheric conditions. This power of absorbing moisture seems to be due to the extremely fine sponge-like structure possessed by these bodies. Such substances are called colloids. They possess properties very different in many respects from the so-called crystalloids or bodies with a crystalline structure, e.g., soda crystals.

Now the precise estimation of the amount of water in such materials as wool (which is expensive and absorbs large quantities of moisture) is of great importance commercially. This amount is specified by means of a quantity called the "regain." The regain of a sample of wool is the amount of water it contains expressed as a percentage of the dry weight (not as a percentage of the total original weight). Thus if a 1lb. sample lost 3oz. on drying, the regain would be 3oz. expressed as a percentage not of 1lb. but of 13oz., i.e., it would be

$$\frac{3 \times 100}{13} \text{ or } 23.08\% \text{ Regain.}$$

The dry weight of 13oz. would have to regain 23.08% to get back to its original weight of 1lb., hence the term "regain."

Standard Regain. For convenience and avoidance of disputes, certain standards of regain are recognised, e.g., 18¼% for yarn. Yarn at this regain is regarded as correct, and if it has more or less moisture, an allowance is deducted from or added to the price. It is by no means certain that the Standard Regains in this country are the most suitable for the climate and for safe storage. Other countries impose other standards. This question is under investigation by the Association.

Dry Weight. The "dry weight" of a sample of wool is defined as the weight obtained by drying the sample in an oven in a current of air at a temperature of from 220° to 230°F. till no perceptible change of weight is detectable in consecutive weighings at an interval of about 8 minutes.

Equilibrium Regain. When wool in any form (top, cloth, etc.) is placed in an atmosphere of constant temperature and humidity, it will in general begin to gain or to lose moisture. This process will go on for some time but at a gradually diminishing rate till finally the wool attains a certain weight and regain. This regain is called the "equilibrium regain." The determination of this equilibrium regain for different humidities and temperatures is a matter of considerable importance.

This information, however, is necessary for the proper understanding and control of certain industrial processes. For example, in French drawing, artificial humidification is necessary for the satisfactory processing of the wool, since the regains corresponding to ordinary indoor conditions are too low. Again, such knowledge of the relation between regain and atmospheric conditions affords information as to the capabilities of a conditioning room for yarn or hosiery. The regain of wool exposed to ordinary atmospheres in this country varies over a wide range—roughly from 30% to 12%. The upper limit would correspond to a nearly saturated atmosphere—the lower to a relative humidity of about 45% (which for our climate is very low).

Stembridge & Co Ltd., Printers, Top of Albion Street, Leeds.